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Exploiting Explicit and Implicit Structure in Complex Optimization Problems

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14. ABSTRACT

A quasi-Newton version of a VU-bundle algorithm for minimizing a convex function, with knowledge of only one subgradient value at each point, was perfected to the point where numerical superlinear convergence could be observed. The algorithm is important, because it is the type needed for minimizing implicitly defined functions resulting from applying decomposition, relaxation and/or dualization techniques to complex real-world optimization problems. Also, valuable research was carried out for nonconvex objective functions. This included a non-VU bundle method for composite functions where the outer function is a positively homogeneous convex function and the inner vector function is a smooth mapping. Such an explicitly known structure separates the two difficulties of nonconvexity and nonsmoothness by allowing only the components of the inner mapping to be nonconvex and only the outer function to be nonsmooth. This new algorithm was shown to be convergent to stationary points and judged to be the best performer out of four methods tested on many examples. Also, significant progress was made on on designing a VU algorithm to run on general semismooth functions. This entailed making a V-model based bundle method subalgorithm with convergence to stationary points.

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Decomposition techniques are often the best choice for solving large scale complex optimization problems. Applications of such techniques in energy planning, generation and distribution are contained in grant supported publications [11], [13], [14], [3] and [5]. The decomposition type of approach involves minimizing a nonsmooth objective function with special structural properties. For (more general) equilibrium problems, similar ideas can be exploited, as explained in publications [5] and [4], dealing with structured variational inequalities resulting from generalized Nash equilibrium problems.

For optimization problems subject to uncertainty, further decomposition methods and structural properties of nonsmooth constrained convex problems are exploited in [1], [7], [10], [14], [3] and [2]. In particular, publication [14] considers a special bundle method, which appears to be computationally effective in chance-constrained programming for optimal management of a set of cascaded hydro-reservoirs. An earlier method that uses inexact objective information for two-stage stochastic programming problems appears in [7]. These methods can be embedded in a more general framework described in [9] and extended in [8] to level bundle variants capable of handling inexact information.

For nonsmooth objective functions, possibly nonconvex, paper [12] develops a computationally effective proximal bundle method for minimizing a composite function where the inner mapping is smooth and the outer function is a positively homogeneous convex function of several variables. Such an explicitly known structure separates the two difficulties of nonconvexity and nonsmoothness by allowing only the outer function to be nonsmooth and only the components of the inner mapping to be nonconvex. This new algorithm was shown to be convergent to Clarke stationary points and judged to be the best performer among four methods tested on several numerical examples.

During the last grant year significant progress was made towards the goal of producing a foundation for designing a future VU-type minimization algorithm to run on semismooth locally Lipschitz functions for which only one Clarke generalized gradient can be computed at a point. Paper [6] gives an excellent illustration of superlinear convergence attained by a VU-algorithm running on a convex objective example. The intent of current work is to attain this fast type of asymptotic convergence if the proposed algorithm gets close enough to a Clarke stationary point that is a strong local minimizer.

The groundwork for the nonconvex case involved development of a 'V-model' based bundle method subalgorithm that has provable convergence to stationary points and can make adequate estimates of 'V-subspace' bases in the presence of nonconvexity. This entailed adding safeguarded second order correction terms to the polyhedral affine subfunction expressions as done in the superlinearly convergent algorithm for the single variable case in [R. Mifflin, Math. Prog. 28 (1984) 50-71].

This work has also produced a very large class of convex model functions for use in bundle methods to obtain asymptotic stationarity for nonconvex objectives. This class contains much more than polyhedral functions, for example, the composite model in [12].

These new research results will be contained in a submission to a special edition of the Journal of Convex Analysis dedicated to the memory of Jean Jacques Moreau, a pioneer in the development of convex analysis.

Publications during reporting period:

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